NASA/CR-97- 206814

FINAL
7N-54-CR
OCIT
051103

NASA FINAL TECHNICAL REPORT: NGT 9-12

December 24, 1997

Title of Grant: Selection and Characterization of Vegetable Crop Cultivars for use in Advanced Life Support systems

Type of Report: Summary of Research: Final Technical Report

Principle Investigator: Robert W. Langhans

Student: David de Villiers

Period Covered: October 1, 1996 to September 30, 1997

Grantee: Cornell University Office of Sponsored Programs, 120 Day Hall, Cornell University, Ithaca, NY 14853

Sponsor: Johnson Space Center, NASA

Grant Number: NGT 9-12 (Cornell OSP# 30562)

Selection and Characterization of Vegetable Crop Cultivars for use in Advanced Life Support systems:

NASA Final Technical Report (NGT 9-12)

December 24, 1997

This report is on work performed by David de Villiers for grant number NGT 9-12, Selection and Characterization of Vegetable Crop Cultivars for use in Advanced Life Support Systems. The grant is also the first installment of a three-year NASA training grant. The aims under the training grant are to first elaborate the theory and technique of cultivar evaluation for controlled environments, then to employ the technique on selected crops, ultimately conducting cultivar trials.

During the period of this report, David de Villiers spent the first semester taking a number of courses and working on his thesis. Courses taken included Principles of Biochemistry, Quantitative Whole Plant Physiology, Research in Plant Breeding, and Measurement of Water Status in Plants; other courses were audited. During the second semester David wrote and defended his MS thesis, Vegetable Cultivar Evaluation and Crop Selection for Controlled Environment Agriculture and Advanced Life Support Systems. This 176-page thesis is available through the Mann Library of Cornell University; copies have also been supplied to NASA personnel (Daniel J. Barta of JSC and Raymond E. Wheeler of KSC). The Abstract is appended.

One of the major differences between cultivar selection for controlled environments and conventional agriculture is that in the former one is interested in productivity (yield over time), in the latter, yield irrespective of time. This makes time of harvest critical in the former case whereas it is not in the latter. It further implies that time of harvest needs to be optimized, and this in turn requires calculation of how cost of production changes with different harvest times. A second major difference is that environmental set-points need optimization in the case of controlled environment agriculture whereas they are a given in the conventional agriculture. Optimization needs to be in terms of cost of production: the key lies in the trade-off between capital cost of the production facility and efficiency of energy use. In highly capital-intensive operations such as Advanced Life Support Systems, cost of production is lowest when production is very intensive, even at the expense of energy-use efficiency. However, this is only within limits.

Following completion of his MS, David spent six weeks as a summer intern at Johnson Space Center under the supervision of his NASA Technical Adviser, Daniel J. Barta, and his thesis chairman, Robert W. Langhans, on sabbatical leave at JSC at this time. The project assigned David was to investigate potential output of a modular Vegetable Production Unit, possibly to be incorporated in Mars Transfer, the Space Station, and other applications. The substantive outcome of this summer internship was a 42-page report on possibilities for such a module. Copies of this unpublished report reside with Daniel J. Barta and others at JSC. "Using 1kW of power for lighting and three compartments of 0.79 m^2, if productivities achievable on earth are achievable in microgravity, it should be possible to produce, every day, one head of butterhead lettuce (5oz), a medium sized spinach plant, a decent sized carrot, and half a pound of tomatoes -- which could be four salad-sized ones. "

After returning to Ithaca towards the end of this grant period, David began preparations for experiments on green bean and dry *Phaseolus* bean for use in the space program. These experiments are currently under way, and will be fully described in subsequent technical reports.

Appendix I

ABSTRACT (of MS thesis)

Cultivar evaluation for controlled environments is a lengthy and multifaceted activity. The chapters of this thesis cover eight steps preparatory to yield trials, and the final step of cultivar selection after data are collected. The steps are as follows:

1. Examination of the literature on the crop and crop cultivars to assess the state of knowledge.
2. Selection of standard cultivars with which to explore crop response to major growth factors and determine set points for screening and, later, production.
3. Determination of practical growing techniques for the crop in controlled environments.
4. Design of experiments for determination of crop responses to the major growth factors, with particular emphasis on photoperiod, daily light integral and air temperature.
5. Developing a way of measuring yield appropriate to the crop type by sampling through the harvest period and calculating a productivity function.
6. Narrowing down the pool of cultivars and breeding lines according to a set of criteria and breeding history.
7. Determination of environmental set points for cultivar evaluation through calculating production cost as a function of set points and size of target facility.
8. Design of screening and yield trial experiments emphasizing efficient use of space.
9. Final evaluation of cultivars after data collection, in terms of production cost and value to the consumer.

For each of the steps, relevant issues are addressed. In selecting standards to determine set points for screening, set points that optimize cost of production for the standards may not be applicable to all cultivars. Production of uniform and equivalent-sized seedlings is considered as a means of countering possible differences in seed vigor. Issues of spacing and re-spacing are also discussed.

In mapping crop response to growth factors, it is proposed that a first set of experiments examine daylength sensitivity and light intensity effects by holding daily light integral constant while varying photoperiod and light intensity. A second set of experiments would vary daily light integral at a fixed photoperiod appropriate to the crop to explore limits on productivity. Temperature would be varied in both sets of experiments.

For most vegetable crops, comparison of cultivars of different maturity date requires discovery of the yield function over the harvest period, from which can be ascertained when productivity is a maximum. At least three harvests timed to bracket the peak in productivity are advised.

Arguments are presented that the most likely and feasible source of superior materials for controlled environments will be from breeding lines currently under evaluation. Fast screening procedures are proposed to ascertain plant characteristics other than yield performance when information is lacking.

Set points for yield trials need to be those for production; appropriate set points cannot be determined without economic analysis of facility cost, labor cost, and cost of supplying inputs.

To economize on space needed for yield trials, I have proposed use of opaque, reflective side walls between cultivars and sample harvest units to replace guard rows and accommodate staggered harvests.

The cost of production index (COPI) is the single most important criterion for cultivar evaluation. For commercial CEA, final selection of cultivars requires market analysis additionally because the cheapest cultivar to produce may not be the best seller. For space life support, post-harvest processing costs need to be included with production costs. The value of superior quality and palatability in fostering well-being of colonists needs to be weighed against additional cost in providing it.

Crop selection for space colonies is addressed in the introductory and penultimate chapters. It is argued that crop selection should be guided from menu in addition to nutritional goals and minimization of cost.